DOI: https://doi.org/10.14505/jarle.v10.8(46).29

Theoretical and Methodological Basis of Fare System Management in Public Transport

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Suggested Citation:

Sokol, K.M. *et al.* 2019. Theoretical and Methodological Basis of Fare System Management in Public Transport, *Journal of Advanced Research in Law and Economics,* Volume X, Winter, 8(46): 2515 – 2522. DOI:10.14505/jarle.v10.8(46).29. Available from: http://journals.aserspublishing.eu/jarle/index

Article's History:

Received 1st of October, 2019; Received in revised form 9th of November, 2019; Accepted 19th of December, 2019; Published 30th of December, 2019.

Abstract:

The research paper considers the issues of ensuring effective management of the processes of transformation of fare systems in public transport. Were analyzed the prospects for implementation of automated fare control systems and also the theoretical and methodological approaches to the formation of existing automated fare systems, which could determine the perspective of implementation of such systems in the domestic market of transport services provision, that can solve a number of problems related with fare simplicity and comfort, formation of a flexible fare system, use of various forms of payment, as well as monitoring and control of money revenues, including for transportation of preferential contingent.

The analysis determined the cost-effectiveness of existing automated fare systems. Were predicted ways to improve the cost-effectiveness of existing automated fare systems through econometric modelling. The introduction of proposals after obtaining of simulation results will identify the potential economic impact and ways to optimize management processes. An analysis of the legal and regulatory framework for the formation and use of automated fare systems concluded that there was insufficient legislative support for the autonomy of management decisions on local public transport systems, in particular under the conditions of the reform of decentralization of power and the formation of integrated territorial communities. Have been developed proposals to improve the legal and regulatory framework for the automation of the management of fare systems in public transport. The analysis identified socio-economic aspects of the introduction of new approaches to the management of

automated fare systems. Was developed an economic and mathematical model to manage automated fare systems in accordance with the conditions of the modern market and socio-economic challenges.

Keywords: automated control systems; fare; control mechanisms; economic and mathematical modeling; public transport.

JEL Classification: K23; R40.

Introduction

In conditions of innovative development and automation of any processes of life activity of society, issues of automation of management of social and economic systems become particularly relevant. The development of the country 's economy can not be imagined without ensuring the effective operation of the transport sector, and ensuring the comfort of the life and welfare of the population are closely linked to the optimization of the public transport system. The issue of passenger fare has an important socio-economic component, because it is closely related to the accessibility of various modes of transport for the public, which in turn affects the workability and social activity of people. Automation of fare control processes in public transport is a pressing challenge in the context of ensuring the European integration trajectory and the formation of new criteria for the quality of transport services. Therefore, it is useful to turn to the subject of automation of the fare control systems in public transport, accumulating the leading world experience and considering specificity of area-based development.

Many scientists dealt with issues of development and implementation of automated fare control systems in public transport, such as Gromov (2013), Sytnyk *et al.* (2001), Palant (2016), Divinets and Palant (2015), Vodovozov *et al.* (2019, 2018), Dimchenko *et al.* (2014), Men'kov and Ostreykovsky (2005), Boyko (2015) and so on. Despite the authors' attention to the fare control processes in public transport, a number of problems in the practical implementation of automation mechanisms, assessment of its economic and social effectiveness, as well as modeling of control processes in order to predict cost-effectiveness, remain unsolved.

The purpose of the article is to develop effective mechanisms for managing the design and application of automated fare systems in public transport to ensure cost-effectiveness. According to the stated purpose, a number of objectives have been identified and solved in the study:

- to analyze theoretical and methodological approaches to the formation of an economic review of existing automated fare systems;
- to determine the cost-effectiveness of existing automated fare systems;
- to develop proposals for modelling ways to increase the cost-effectiveness of existing automated fare systems;
- to analyze legal and regulatory framework legal for the formation and use of automated fare systems, to develop proposals for its improvement;
- to identify socio-economic aspects of the introduction of new approaches to the management of automated fare systems;
- to develop an economic and mathematical model for the management of automated fare systems in accordance with modern market conditions and socio-economic challenges.

1. Characteristic of the Efficiency of Public Transport as a Systemic Category

Factors that affect the quality and availability of transportation services include passenger transportation safety, speed and compliance with traffic schedules, comfort for passengers, fare and other factors. Consequently, improving the efficiency of public transport is a factor in the socio-economic development of the country. The public transport system in Ukraine today has considerable technical and technological wear. The issue of modernization and technical re-equipping of all transport infrastructure is closely related to the issues of quality of service provision, safety and comfort of passenger transportation. However, the problem of finding financial resources for the implementation of large-scale programs of technical and technological re-equipment, modernization, that determines the relevance of finding ways to effectively manage the fare systems in public transport.

With the urbanization of the territory and the constant growth of the urban population, public transport takes on strategic importance in the rational functioning of the modern city, determining the attention of both domestic and world specialists to the solution of transport problems. After all, it is the development of the transport network that contributes to the processes of labor reproduction, productivity growth, raising of living standards of the population, cultural growth and psychological health (Gromov 2013).

In order to further analyze fare systems in public transport, it is useful to analyze the factors that contribute to the development of public transport in urban areas, among them we will highlight the following (Sytnik *et al.* 2001, Palant 2016): urban population growth; increase in passenger traffic and load per vehicle; formation of

agglomerations and expansion of urban boundaries; development of passenger requirements to the travel speed and overcoming long distances; increase of comfort level for passengers; development of inter-residential ties and, as a result, development of long-distance public transport network and other.

At the same time, the economic factor in the movement of person plays one of the most important roles. Under equal conditions, the passenger will choose the type of public transport that is more economically profitable. The generally accepted models of fare in Ukraine are outdated, that negatively affects the growth of passenger traffic and drags on the growth of the economy as a whole. Among the shortcomings of the existing fare systems for public transport in Ukraine, we will highlight the following (Divinets and Palant 2015, Vodovozov and Palant 2019): strict fare algorithm, lack of transparent and clear control over the transport of the preferential contingent and the absence of compensation for payment for the provision of such services; lack of clear control of passenger flows, lack of automated passenger registration systems and fare verification system, inefficient organizational and economic mechanisms for collecting fare and monitoring their implementation, absence of information security systems, practical absence of counterfeit protection, lack of statistical information on passenger traffic formation and impossibility of making balanced management decisions, use of different types of traffic documents on different modes of public transport.

World practice shows that the following actions are necessary to solve this problem (Vodovozov *et al.* 2018, Dimchenko *et al.* 2014, Men'kov and Ostreykovsky 2005):

- transfer of transport companies to the private sector through public-private partnership projects;
- automation of fare systems and control of the acquisition and use of payment means;
- informatization of passenger traffic monitoring systems;
- analysis and rationalization of transport routes.

So, one of the ways to increase the economic efficiency of public transport is to automate the processes of passenger registration, control and monitoring of fare and informatization and digitalization of transportation.

Consider in more detail the existing systems of automatic control of passenger traffic and fare, which demonstrated efficiency in practical application. One of common practice of automation of fare systems is the use of a contactless mobile module responsible for collecting, analyzing and optimizing passenger traffic taking into account the specifics of solving transport problems of a particular city. The module of interaction with automated systems of traffic scheduling not only performs analysis of passenger traffic, but also their rationalization in accordance with the time of day and load on a particular route, which allows to rationalize it after analysis of statistical information (Boyko 2015).

Owing to Near Field Communication (NFC) system, developed by the world's leading corporations Philips and Sony, ticket scanning is done via wireless technology at a distance. The interface of the processor built into the phone owing to a special application allows the operator to read information about passenger traffic and fare. Passengers pay automatically through the application, choosing the number of trips and paying with a bank card the fare for the selected period automatically. The hardware and software complex encrypts the information, transmits it to the operator, and sends an electronic ticket to the passenger's phone in feedback.

This module automates the following processes (Boyko 2015):

- purchase and issuance of electronic payment means;
- use of bank transaction for public transport fare;
- use of e-payments;
- collection and analysis of passenger traffic statistics.

Similar technologies have been made possible by the NFC based on SIM-cards, built-in mobile phones of most brands, which allows to use transport applications. Similar systems have already been developed and are used on transport networks of Japan, Germany, USA, Great Britain, France, Italy, South Korea, Turkey and other countries of the world. A number of companies developing automated control systems in transport offer packaged offers with automatic fare collection. For example, the automatic fare collection of CS-Trans (KS Mechatronics, 2013), control configuration of which is presented in Figure 1.

Advantages of such a system: improving the monitoring of fare; automation of processes of collection and processing of information on fare; accounting for transportation of preferential categories of passengers; absence of negative impact of the 'human factor' when paying for travel; protection against counterfeiting of traffic documents; rationalization of transportation management systems; possibility to introduce 'flexible' forms of fare (discounts, tariffication models, etc.).

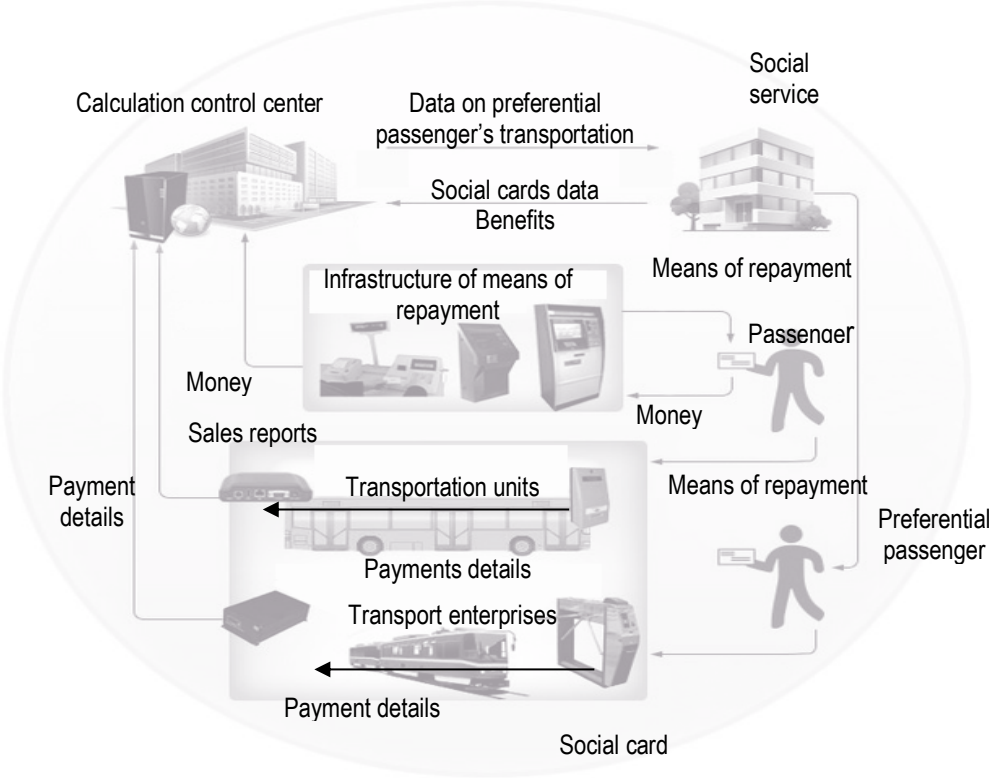
Another automatic fare system described in (Automatic fare and passenger 2019) has the following capabilities: automation of transport services accounting; automated fare accounting; automated ticket printing;

automatic transfer of information to the central operator and its storage in the system. Operation of such type of automated fare control system is shown in Figure 2.

Thus, by analyzing the cost-effectiveness of automated fare control systems in public transport, can be identified the following indicators, that have a significant impact on efficiency:

- clear control and fare accounting excludes the 'human factor', that increases the level of income of public transport enterprises;
- statistical accounting by using automated fare control systems allows to optimize routes according to passenger traffic data, which not only increases the profitability of the enterprise, but also increases the quality of provided transport services, their safety, reduces wear and affects the depreciation of rolling-stock and other elements of transport infrastructure of public transport enterprises;
- automated fare control systems help to cut the number of fare inspectors and controllers, resulting in savings in wages fund, social expenditures and taxes, while providing workplaces for skilled IT professionals and designer/technologists.

Figure 1. Automated fare system CS-Trans



Source: Based on KS Mechatronics (2013).

So, mathematically, the cost-effectiveness of using automated fare control systems in public transport may be represented as a function (Equation 1):

$$\int AFS = \int (I + ERF + TC + TS + D + W + SB), \quad (1)$$

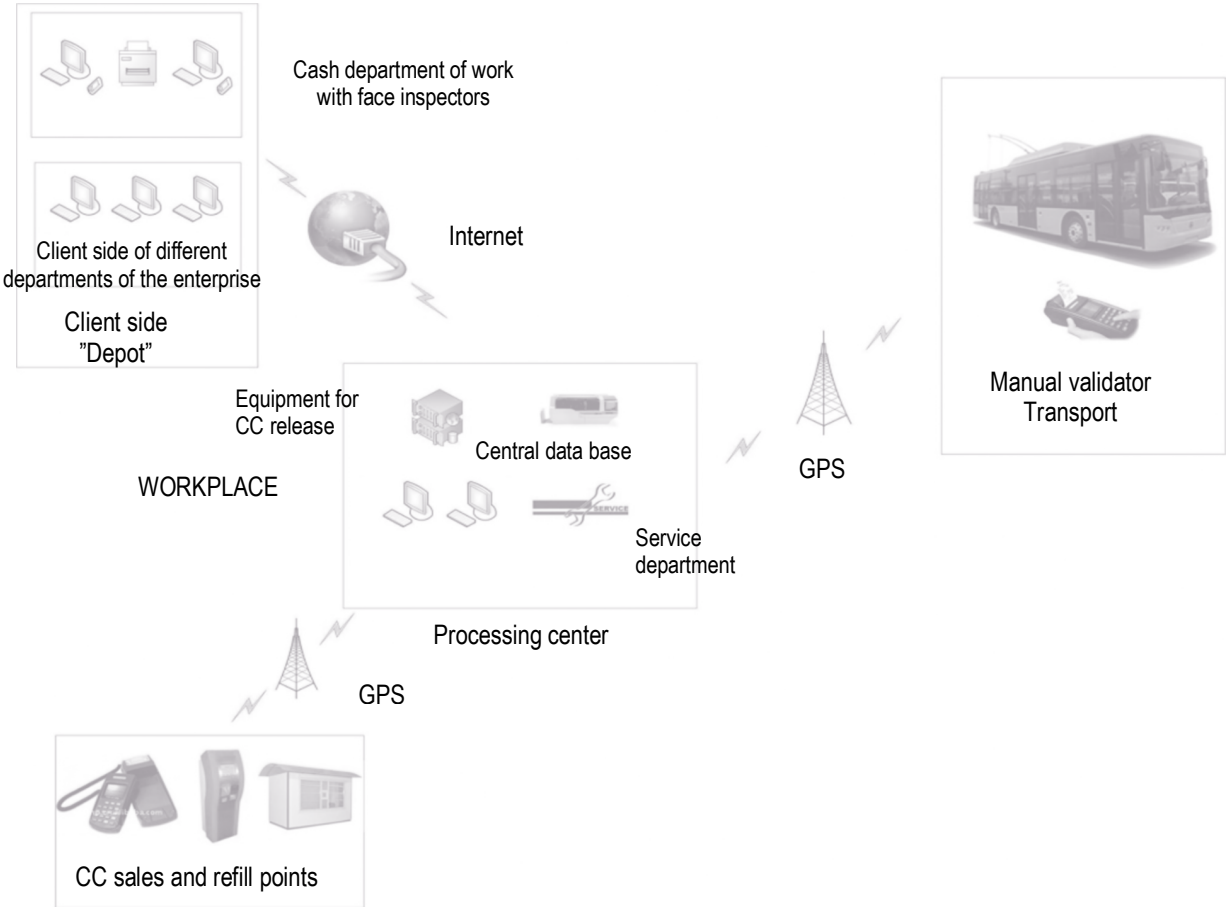
where: AFS – automated fare system; I - incomes of public transport enterprises; ERF - extra revenue of fare, generated by rationalization of passenger traffic accounting processes; TC - improving transportation comfort, which is economically determined in increase of passenger traffic; TS - improving transportation safety, which is economically reflected in reduction of costs for renewal of rolling-stock after accidents; D - savings from reduced depreciation cost and repair costs for rolling-stock by route rationalization; W - surplus earnings from wages fund reduction to fare inspectors and controllers; SB - surplus earnings from payment of social benefits to fare inspectors and controllers.

So, we can identify a number of advantages of automated fare control systems from those that are mostly common in domestic public transport:

- wide coverage of functions and processes of transport services, that can be automated in parallel with automation of fare, has additional technical and economic effect;

- clear monitoring and control of passenger traffic, which allows not only to increase the profitability of public transport enterprises and minimize the 'human factor', but also to optimize routes based on the results of analysis of passenger traffic data;
- introduction of e-payments;
- monitoring and control of the registration of passengers of the preferential contingent;
- counterfeit protection and information security;
- improving transport comfort and traffic safety by optimizing the transport network;
- reduced costs of printing tickets and other traffic documents.

Figure 2. Operation of automated fare control system



Source: Based on Automatic fare and passenger check system electronic resource (2019).

2. Analysis of the Regulatory Framework Governing the Operation of Public Transport Enterprises

Another important lever for improving the efficiency of public transport enterprises is to update the regulatory framework for the operation of these enterprises. For example, the regulatory support fare system consists of the following regulatory documents, as analyzed in Table 1.

Table 1. Regulatory support fare system of public transport

Name	Description
Law of Ukraine 'On Local Self-Governance in Ukraine' (1997)	▪ defines the powers and responsibilities of local self-government bodies to form a cost-effective, optimized transport network;
Law of Ukraine 'On road transport' (2001)	▪ 'defines the basis for the organization and operation of road transport' (Law of Ukraine 'On Road Transport' 2001);
Law of Ukraine 'On Urban Electric Transport' (2004)	▪ 'defines the legal, organizational and socio-economic foundations of the functioning of public urban electric transport in the transport services market and aims at creating favourable conditions for its development, satisfying the requirements of citizens for accessible,

Name	Description
	quality and safe transport' (Law of Ukraine 'On Urban Electric Transport' 2004);
Law of Ukraine 'On Amendments to Certain Legislative Acts of Ukraine on Introduction of an Automated Fare Accounting System in Urban Passenger Transport' (2017)	▪ defines the provision 'for the introduction of an automated fare accounting system and the establishment of the procedure for its operation, as well as the types, forms of carriers, the procedure for the circulation and registration of traffic documents; identifies the person authorized to charge for transport services in case of the introduction of an automated fare accounting system' (Law of Ukraine 'On Amendments to Some Legislative Acts 2017);
Resolution of the Cabinet of Ministers of Ukraine 'On free travel of pensioners in public transport' (1993)	▪ defines the system of granting benefits to social categories of the population;
Rules for the provision of passenger road transport services approved by the Resolution of the Cabinet of Ministers of Ukraine (Resolution of the Cabinet of Ministers of Ukraine 'On rules…1997)	▪ define rules for passenger handling by road, including mechanisms of fare formation and fare system;
Rules for the provision of urban electric transport services to the population, approved by the Decree of the Cabinet of Ministers of Ukraine (2004)	▪ define rules for passenger handling by urban electric transport, including mechanisms of fare formation and fare system;

The analysis of the legal framework on this issue showed that the technical and economic development objectives of public transport center around the powers and responsibilities of local self-government bodies. The Cabinet of Ministers of Ukraine has developed a number of rules regulating procedures for the formation, optimization of the transport network, fare calculation and establishment of fare mechanisms. The Law of Ukraine 'On Introducing Amendments to Certain Legislative Acts of Ukraine on the Introduction of an Automated Fare Accounting System in Urban Passenger Transport' defines the procedure for the introduction of automated fare accounting systems in urban passenger transport. In particular, this Law reflects (Law of Ukraine 'On Amendments to Some Legislative Acts 2017):

- the wording of the definition 'an automated fare accounting system is a software and hardware package designed to carry out accounting of provided transport services by means of an electronic ticket' (Law of Ukraine 'On Amendments to Some Legislative Acts 2017);
- powers and responsibilities of local self-government bodies on the application of the automated fare systems: 'The rules for the use of urban electric transport are approved by the relevant local self-government bodies. They define the procedure for travel and payment procedure, the rights and obligations of passengers, as well as the relationship between carriers and passengers in the provision of transport services, taking into account the features of transport infrastructure and the availability of an automated fare accounting system' (Law of Ukraine 'On Amendments to Some Legislative Acts 2017);
- 'local self-government bodies shall introduce an automated fare accounting system, establish the procedure of its operation, as well as forms of carriers, types, procedure for circulation and registration of traffic documents, which determine the person authorized to charge for transport services in case of introduction of an automated fare accounting system' (Law of Ukraine 'On Amendments to Some Legislative Acts 2017).

Thus, the analysis of the legislative framework showed that local self-government bodies have broad powers to provide technical and economic support for public transport. At the same time, indeed, there are no uniform approaches to the formation of a cost-effective fare system. Public transport utilities are unprofitable and need effective management mechanisms to ensure sustainable financial and economic development. Under the conditions of expanding the powers of local self-government bodies through decentralization actions, an important aspect of improving the system of regulatory and legal support for the implementation of automatic fare control system is the formation of recommendations for local authorities and united territorial communities on the cost-effectiveness of such a fare system and the development of mechanisms for its step-by-step introduction. It is also useful to identify socio-economic aspects of the introduction of new approaches to the management of automated fare systems. The social benefits of effective fare mechanisms include:

- improving the fare simplicity and comfort by using different payment methods: cash, bank payment, online payment, mono-bank, etc.;

- socially just fare for preferential categories of the population, control, clarity and transparency of benefits;
- variety of traffic documents to satisfying the requirements of different sectors of passengers: one-time tickets, electronic contactless travel cards, online applications, etc.;
- possibility to form a discount system and a flexible price policy on the fare;
- universality of means of payment for different modes of transport;
- increase of safety, comfort and quality of passenger service;
- reduction of the cost of fare due to reduction of employees and optimization of fare;
- a possibility of retraining of fare inspectors and controllers and recruitment of the staff which activity is directed to increase in level of quality of service of passengers;
- increase in the information component of passenger service through the use of information desks and informational advertisements defining the main traffic indicators for passengers.

Describe the criterion of fare using econometric dependence of 'manual' fare control system and automated system, creating a generalized economic and mathematical model. Perform a pair comparison of the resulting indicators. At the same time, dependency A is defined as system control in 'manual' mode, and dependency B as automatic control. The resulting indicators are determined as: X - passenger traffic; Y - incomes of transport enterprises from fare; Z - reduction in cost of transportations (Equation 2):

$$E = \frac{Xa}{Yb} + \frac{Ya}{Yb} + \frac{Za}{Zb} / 3 \quad (2)$$

where: Xa, Xb - planned passenger traffic at 'manual' (A) and automated (B) fare control; Ya, Yb - expected incomes from fare at 'manual' (A) and automated (B) fare control; Za, Zb - plan indicators of transportation cost reduction at 'manual' (A) and automated (B) fare control.

Based on the results of the formula used to evaluate the cost-effectiveness of the selected fare control model, it is determined that the lower the integrated factor E, the higher the performance evaluations of the effect of the introduction of the automated fare control system. By analyzing this model, it can be determined that the authorities of transport systems (enterprises) should introduce automated models of fare to ensure the cost effectiveness indicators of their functioning.

Conclusions

Thus, the article analyzed the challenges and prospects for the introduction of automated fare control systems. The economic and socio-economic efficiency of such introduction ss determined, which is connected with improvement of quality, safety and comfort of transport, increase of passenger traffic and increase of profitability of carrier enterprises from provision of transport services. The cost-effectiveness models for application of automated fare control systems in public transport systems are developed and the econometric dependence between manual and automated fare control is determined. As the result of the analysis, was determined the feasibility of using automated systems of fare control in domestic public transport; was developed the economic and mathematical model of control of automated fare systems in accordance with the conditions of the modern market and socio-economic challenges.

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